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HOT TOPIC

Direct-to-Consumer Genetic Testing and Personal Genomics Services: A Review of Recent Empirical Studies

J. Scott Roberts · Jenny Ostergren

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Abstract Direct-to-consumer genetic testing (DTC-GT) has sparked much controversy and undergone dramatic changes in its brief history. Debates over appropriate health policies regarding DTC-GT would benefit from empirical research on its benefits, harms, and limitations. We review the recent literature (2011-present) and summarize findings across (1) content analyses of DTC-GT websites, (2) studies of consumer perspectives and experiences, and (3) surveys of relevant health care providers. Findings suggest that neither the health benefits envisioned by DTC-GT proponents (e.g., significant improvements in positive health behaviors) nor the worst fears expressed by its critics (e.g., catastrophic psychological distress and misunderstanding of test results, undue burden on the health care system) have materialized to date. However, research in this area is in its early stages and possesses numerous key limitations. We note needs for future studies to illuminate the impact of DTC-GT and thereby guide practice and policy regarding this rapidly evolving approach to personal genomics.

Keywords Genetic testing · Consumer genomics · Health ethics · Health policy · Personalized medicine

Introduction

Given the rapid pace of progress in the field of consumer genomics, it may seem like ancient history when *Time* magazine named "The Retail DNA Test" as its 2008 Invention of the Year, and *Nature* cited "Personal Genomics Goes Mainstream" as a top news story [1, 2]. The past five years have witnessed widespread scientific and social enthusiasm about—and controversy over—new developments in whole genome sequencing technologies and their possible commercial applications to human health. Many proponents of consumer genomics—including direct-to-consumer genetic testing (DTC-GT) marketed publicly to individuals and made available without need for an intermediary medical professional—view direct access to one's genome as an individual right, noting many potential benefits of learning more about one's predilection to disease and likelihood of response to particular medications. Meanwhile, professional organizations representing health professionals and genetics researchers have continued to express concerns regarding DTC-GT and its potential harms [3, 4].

In recent years, many notable changes have occurred in the field. Decreasing genotyping costs have resulted in DTC-GT services becoming more accessible to the average consumer; for example, 23andMe, a leading company in the field, now offers its services for $99 (as compared to an original price of $999 in 2007) [5]. Another recent development is that many companies have either left the marketplace or moved from a pure DTC model toward one involving partnership with physicians and health care systems [6]. This shift can be attributed in part to intensified regulatory pressures in 2010, when the US Food and Drug Administration (FDA) sent warning letters to several DTC-GT companies and the Government Accountability Office (GAO) issued a highly critical report of the industry, declaring test results to be "misleading and of little or no practical use" and concluding that two-thirds of companies investigated "engaged in some form of fraudulent, deceptive, or otherwise questionable marketing practices" [7].

J. S. Roberts (✉) · J. Ostergren
Department of Health Behavior and Health Education, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109, USA
e-mail: jscottr@umich.edu

Despite the considerable amount of attention accorded to consumer genomics, there have been relatively few empirical studies in this area. Numerous policies have been developed within the US and abroad to regulate the provision of DTC-GT services [8], and recommendations have been provided to both consumers and health care professionals [9, 10]. However, data are needed across multiple areas to guide future practice and determine whether existing regulations strike an appropriate balance between consumer and commercial sovereignty on one hand and safeguards to ensure the public's health on the other. Topics of particular interest include (1) content of DTC-GT company education and marketing materials, (2) consumer responses (e.g., psychological, behavioral) to learning their personal test results, and (3) perspectives and experiences of health care professionals affected by the provision of DTC-GT services. We review and comment on the recent literature (2011–2013) in these domains to help evaluate the potential benefits, harms, and limitations of DTC-GT and related personal genomics services, and to identify areas of need for future research.

Methods

PubMed searches were conducted between February–April 2013 to retrieve peer reviewed articles focused on DTC-GT. Articles were restricted to those published in English since January 2011. We excluded papers that were concerned with DTC marketing strategies or only included brief mention of DTC-GT. Search terms included "direct-to-consumer" AND "genetic" or "genomic," and "personal genomics." A total of 94 articles were initially identified. Of these, we excluded those that were not primary sources of data (e.g., commentaries, review articles) and/or that did not focus on health-related issues (e.g., articles on DTC-GT ancestry testing), yielding a final sample of 39 articles. A classification scheme was then developed to organize the presentation of findings from these articles across broad topic areas including: (1) content analyses of DTC web sites, (2) consumer perspectives and experiences, and (3) perspectives of health care providers. Given space constraints, we do not report on all identified articles but these are included in Appendix Table 1, which lists the 39 studies and provides brief descriptions.

Results

Content Analyses of DTC-GT Website Information

Three studies examined content on DTC-GT websites to understand how companies represent their health-related services and the potential implications for consumers. Singleton et al. [11] conducted a content analysis of 23 DTC websites and found that statements about the benefits of testing outnumbered risk and limitation statements by a 6:1 ratio. The most frequently described benefits were: (1) disease prevention, (2) consumer education, (3) personalized medical recommendations, and (4) the ability to make health decisions. Although the vast majority (78 %) of websites noted at least one limitation of testing (e.g., most tests are not suitable for clinical use), only 35 % mentioned any test risks (e.g., worry/anxiety). The authors concluded that website descriptions of DTC services might give potential consumers an inaccurate sense of the potential pros versus cons of testing, undermining their ability to make a fully informed decision. In a related qualitative analysis, Arribas–Ayllon, Sarangi, and Clarke explored rhetorical and discourse approaches used on three DTC-GT websites [12]. The authors identified three distinct approaches to managing access to personal genetic information: (1) a 'paternalistic' approach that utilizes the medical model by emphasizing the medical professional as the mediator between consumer and genetic information; (2) a 'translational' model (i.e., from bench scientist to consumer) that emphasizes scientific quality and accuracy, with the laboratory scientist as mediator between consumer and genetic information; and (3) a 'democratic' register where access to personal genetic profiles is largely unmediated, with service delivery enhanced by sharing of information among user communities and consumer-led engagement.

Harris, Kelly, and Wyatt focused on the role of genetic counselors as depicted on DTC websites, blogs and related online materials [13]. They identified four representations of genetic counseling—integrated counseling, discretionary counseling, independent counseling, and product advice—each of which places counselors in the role of "personal genetics experts" in which they may be expected to serve as genetic educators, mediators, lifestyle/health advisors, risk interpreters, or even entrepreneurs. The findings demonstrate that the integration of genetic counseling into DTC-GT services is contributing to a diversification of roles and expectations within this profession.

Consumer Perspectives and Experiences

Awareness of DTC Testing

Several recent studies have explored consumer awareness of DTC-GT services in the US. Using a nationally representative set of cross-sectional surveys, Finney Rutten et al. [14] examined population-level changes in DTC-GT awareness and found a significant increase from 2008 to 2011 (29 to 37 %). Awareness was significantly higher

among the following groups: individuals aged 50–74, college graduates, persons with a regular health care source, those with a prior diagnosis of cancer, Internet users, and urban residents. In a related study, Hall et al. [15] compared awareness of DTC-GT between individuals with cancer and their first-degree relatives and an unaffected control group. Among the 1,267 survey respondents, 49 % were aware of DTC-GT, with the high-risk group demonstrating a significantly greater level of awareness than controls. Data from four states using the 2009 Behavioral Risk Factor Surveillance System suggested regional differences in DTC-GT awareness (e.g. awareness was nearly twice as great among Oregon residents versus Michigan residents), with higher awareness associated with higher education, higher income, and increasing age (excluding those 75 years and above) [16].

Two studies examined awareness of DTC-GT among different racial/ethnic groups. Ortiz et al. [17] used data from the 2009 Health Information National Trends Survey (HINTS) in Puerto Rico to determine prevalence of DTC-GT awareness among Puerto Rican adults, finding a majority (56 %) of respondents to be aware of these services. Those who were married or current smokers were less likely to be aware, while those who had sought cancer information were more likely to be aware. Langford et al. [18] used HINTS data from 2007 to investigate the association between race/ethnicity and DTC-GT awareness. Black (23.8 %) and Hispanic (29.7 %) respondents had significantly lower rates of awareness as compared to white respondents (35.1 %); however, the association between black race and awareness weakened when numeracy was added to the model, suggesting this variable as a potential mediator.

Test Motivations and Interest

Several studies have examined motivations, perceptions and intentions of both actual and potential users of DTC-GT and related services. Gollust et al. [19] surveyed early adopters of personal genomics through the Coriell Personalized Medicine Collaborative (CPMC), a research-based study of personalized medicine. They found that members' main motivations for pursuing personal genomics services were curiosity about their genes (81 %), a desire to find out about risk for disease (78 %), and to improve their health (78 %). Fewer respondents noted the importance of learning about health risks of their children and grandchildren (47 %) and an interest in specific medical conditions (38 %). In an exploratory study of users' personal stories on Internet blogs and DTC-GT web sites, Su, Howard and Borry identified five sets of motivations and expectations related to (1) health, (2) curiosity and fascination, (3) genealogy, (4) contributing to research, and (5) recreation [20]. The authors concluded that improving health was the main motivation for DTC-GT consumers.

Two other studies examined how different ways of presenting individuals with information about the potential risks and benefits of DTC-GT may affect motivations or intentions to get tested. Gray et al. [21] conducted a randomized, controlled trial to explore the impact of genetic risk information presented on a mock *BRCA* DTC-GT testing web site. A sample of 767 women was either presented with information on the risks of DTC testing (intervention group) or not (control group). The intervention group reported fewer positive beliefs about DTC-GT, lower intentions to get online *BRCA* testing, and a higher level of preference for clinic-based testing. In another study examining the effect of information content on intentions and attitudes toward testing, Sweeny and Legg provided participants with three types of information about DTC-GT: positive only, negative only, or both [22]. As compared to the negative and full information conditions, participants in the positive only group perceived the greatest benefits and fewest barriers to testing, showed more anticipated regret over not testing, and reported greater intentions to pursue testing. Thus, the authors concluded that exclusively positive information may promote interest in testing, whereas the intentions and interest of those receiving exclusively negative information may not differ from those receiving balanced or full information.

Comprehension and Interpretation of Test Results

Studies of DTC-GT consumers' understanding suggest that the vast majority "get the gist" of their test results. For example, in a prospective assessment of participants in the Multiplex Initiative who had undergone genetic susceptibility testing for eight health conditions, Kaphingst et al. [23] found that 80 % of participants correctly recalled their results and that they were unlikely to perceive their results as deterministic (i.e., they recognized that disease causes were multifactorial). Similar results were found in a report from Gordon et al. [24] on 60 participants in the CPMC. In a related study, Kaufman et al. [25•] surveyed 1,048 consumers of three personal genomics companies (Navigenics, 23andMe, and deCODEme). Respondents were posed hypothetical scenarios of susceptibility testing for type 2 diabetes and colon cancer, with results presented in the same online format as their own personal results would have been (e.g., Navigenics customers were shown results using a display template from a Navigenics company test report). Results showed that 90–94 % of respondents showed risk accuracy when interpreting test results. Likelihood of a correct response was associated with younger age and higher among those who reported that test reports were easy to understand.

However, some evidence exists regarding the potential for public misperceptions about personalized genomic test results. In their study of 369 enrollees of the CPMC, Gollust et al. [19] noted that most participants did not express deterministic perspectives about genetics, but found that a significant subset (32 %) believed there were no risks involved in CPMC testing and that they would receive risk information for all genetic diseases. Leighton, Valverde, and Bernhardt, in a comparison of lay public versus genetic counselor perceptions and understandings of DTC test results using an online survey on Facebook, also found evidence for relatively common public misinterpretation of test results [26]. Although the majority of the public respondents interpreted test results correctly across four mock scenarios (e.g., genetic susceptibility testing for colon cancer and heart disease), significant differences were observed between the general public and genetic counselors in three scenarios. For example, public respondents showed lower levels of risk accuracy in interpreting results and were more likely to overrate the benefits of testing in informing future disease management and health care. The authors also found that many respondents demonstrated an inability to accurately assess whether they would benefit from assistance in interpreting their results. Finally, James et al. [27] examined risk perceptions among a sample of preventive medicine clinic patients, half of whom were randomized to receive DTC-GT risk information for 12 conditions on top of their usual care. The authors observed that while patients who received DTC genetic risk information generally rated their risk of common diseases similarly to patients who did not receive this information, they perceived their risk as slightly higher for lesser known, rarer conditions (e.g., abdominal aneurysm, Graves' disease). Findings suggest that DTC-GT may have a greater effect on risk perceptions or individual interpretation of results when less is known about the condition at baseline.

Psychological Impact of Results

Several studies have examined actual or potential psychological effects of receiving DTC-GT results. Studies posing hypothetical scenarios to participants suggest the potential for increased psychological distress and anxiety in response to positive test results. Bansback et al. [28] used a web-based survey to elicit participant interpretations of hypothetical genetic risk profiles and test results, and found that across all scenarios 40 % of participants anticipated feeling more worried and anxious after seeing their genetic profile, with higher levels of disease risk associated with greater anticipated worry and anxiety. In another study, participants who received a mock report about their genetic susceptibility to alcoholism exhibited increased negative affect, decreased positive affect, and reported less perceived control over drinking problems, suggesting that there may be immediate psychological effects to receiving personalized genetic information [29].

However, studies that have enrolled recipients of actual personalized test results have generally shown little significant impact on psychological well-being. Bloss, Schork, and Topol collected longitudinal data (with follow-up 6–8 months on average) on self-reported symptoms of anxiety in a sample of 2,037 participants who received genetic risk information via the Navigenics Health Compass DTC-GT service [30••]. The study found no significant differences in anxiety symptoms between baseline and follow-up, and that the vast majority (90.3 %) of participants did not evidence significant test-related distress (although distress was positively correlated with average estimated lifetime risk for all conditions). The aforementioned James et al. [27] study found no significant between-group differences in worry about the 12 conditions tested for in that project, suggesting that receiving DTC-GT information did not elevate disease-specific concern among patients attending a preventive medicine clinic. Finally, Egglestone, Morris and O'Brien conducted an online survey with a convenience sample of 189 individuals who had reportedly received health-related DTC-GT results. They found that a minority of respondents (24.6 %) reported a change in health-related anxiety in response to their test results, and that the vast majority of these respondents (85.3 %) noted a *reduction* in anxiety [31].

Not all studies of psychological response to DTC-GT results have focused on general reactions to risk information for multiple diseases at once. Two have addressed response to *BRCA* 1/2 testing, one of the few DTC-GT tests for high-penetrance mutations. Reporting on a recent genetic counseling case of a client who unexpectedly discovered a *BRCA* mutation after DTC-GT, Dohany et al. [32] noted that a lack of pre-test counseling left their client unprepared for her positive test result. The client reported significant psychological distress (including insomnia) upon learning her result and confusion about how best to respond. After a comprehensive in-person genetic counseling consultation, the client reported a significant reduction in anxiety and initiated risk-reducing surgery and increased surveillance. The authors concluded that pre- and post-test genetic counseling are an important means of countering patient distress and encouraging patients to be proactive in their use of test results. A contrasting report in this area comes from Francke et al. [33•], who reported on results from 136 high risk individuals who had received *BRCA* mutation-positive reports through 23andMe's Personal Genome Service. Among 32 participants who agreed to interviews about their experience of learning test results, there was no indication of extreme anxiety, and only four

instances of moderate anxiety of short duration. Nearly all carriers (31/32) reported that they appreciated learning their *BRCA* mutation status, even if the information was unwanted and unexpected.

Health Behavior Changes

Several studies have examined whether the provision of DTC genetic risk information results in notable health behavior or related lifestyle changes. Kaufman et al. [25•] conducted an online survey of 1,048 customers of 23andMe, DeCODEme and Navigenics to see how the interpretation of their results affected customer health behavior and health care use. Sixteen percent of respondents changed a medication or supplement regimen, one-third reported being more careful about their diet, and 14 % reported increased amounts of exercise (there was no comparison group in this study). Participants who consulted a health care provider were more likely to engage in health behavior changes. On a similar note, the aforementioned survey from Egglestone et al. [31] found that 27 % of DTC-GT consumers reported positive or neutral health behavior changes in response to their personal tests, such as a "healthier diet" or "more exercise". Conversely, Bloss et al. [30••] observed no significant health behavior changes in response to DTC-GT information. They found that among participants who received genetic risk information from the Navigenics Health Compass service, there were no significant differences between baseline and follow-up in dietary fat intake and exercise behavior. In a follow-up study with this sample (data collected approximately one year after DTC-GT results were provided), Bloss et al. [34] found that those who shared their test results with a physician reported engaging in a greater number of screening tests (e.g., for diabetes, prostate cancer) than those who did not share their results with a physician.

Health Care Utilization

Several studies have examined the potential effects of DTC-GT information on the health care system. One area of interest has been the extent to which DTC-GT consumers share their personal test results with their physicians or other health care providers. In the aforementioned Kaufman et al. [25•] study, about a quarter of participants (28 %) overall reported discussing their results with health care professionals; 20 % had discussed with their primary care provider (PCP), while only 1 % had discussed with a genetic counselor. The previously discussed Bloss et al. [30••] study had a similar finding, as a quarter of participants (26.5 %) reported sharing their results with their physician, while only 10.4 % discussed their results with a freely available Navigenics genetic counselor. This study also found no significant increases from baseline in the use of screening tests such as mammography, colonoscopy, and glucose or cholesterol tests.

Perhaps the most dramatic example of the potential health care impact of DTC-GT results comes from the aforementioned Francke et al. [33•] study of individuals who received *BRCA* mutation-positive DTC-GT reports. Of 11 mutation-positive women receiving their *BRCA* status for the first time, four had already engaged in risk-reducing procedures (one prophylactic mastectomy, three oophorectomies) after confirmatory testing, with seven others planning to pursue such surgeries in the future. The majority of mutation-positive participants reported sharing their results with family members, leading to 30 additional (secondary) *BRCA* tests, 13 of which reportedly resulted in carrier identification. Within these secondary cases, several women had reportedly also undergone risk reduction surgeries, and one case of early, non-invasive breast cancer had been detected.

Relatively few studies have conducted formal analyses of health services utilization in response to personalized genetic test results. Reid et al. [35•] analyzed data from 1,599 continuously insured adults aged 25–40 who were offered genetic susceptibility test information for eight conditions (e.g., colon and lung cancers, heart disease, diabetes) as part of the Multiplex Initiative. Health care utilization was measured in 12-month periods, both pre- and post-testing, across three groups: (1) participants who completed a baseline survey only; (2) those who also visited the study website; and (3) those who actually opted for and received their personal test results. Utilization was measured in terms of physician visits and medical screening procedures (e.g., colonoscopy, glucose and cholesterol tests, chest X-ray) associated with four of the conditions of interest. The researchers found that receipt of DTC-GT results was not associated with an overall increase in health care utilization, although the study group that elected testing showed higher use of physician visits prior to testing than the two comparison groups. These findings suggest that DTC-GT results were not leading to a cascade of follow-up tests and procedures.

Perspectives of Health Care Providers

Given that consumers may first turn to PCPs for help with interpreting and acting upon their test results, PCPs have been the focus of recent surveys examining attitudes, beliefs and experiences regarding DTC-GT. A survey of 382 PCPs in North Carolina found that 85 % reported feeling unprepared to answer patient questions regarding DTC-GT testing (with female providers more likely than male to report feeling unprepared), and that a majority (61 %) were unaware of such testing in the first place [36, 37]. However, the vast majority (74 %) reported wanting to

learn more about DTC-GT. Of those who were aware of such testing, 43 % reported believing that it was clinically useful (with family practitioners more likely than internists to report that testing was useful), and 19 % reported having already had patients come to them with their own DTC-GT results.

Two studies assessed the perspectives and experiences of genetic health professionals. Hock et al. [38] surveyed 312 members of the National Society of Genetic Counselors and found that the vast majority of respondents (83 %) had received two or fewer inquiries about DTC-GT, with 14 % having received requests to interpret test results. Most respondents believed that they had a responsibility to be knowledgeable about DTC-GT (55 %) and to interpret test results (48 %), and 56 % thought that DTC-GT was acceptable if followed up with genetic counseling. Notably, over 70 % of respondents indicated that they would consider referring a patient to a DTC-GT company under select conditions, and 90 % would do so if there were geographic constraints to obtaining genetic testing. In a study conducted in Australia and New Zealand, 130 genetic counselors and 38 clinical geneticists from the Human Genetics Society of Australasia completed an online survey to assess their views on DTC-GT [39]. Only a small minority of respondents (7 %) reported that they felt confident in accurately interpreting and explaining DTC-GT results. Eleven percent responded that a client had been referred to them after receiving DTC test results. Most respondents did not feel that DTC-GT was useful for anonymous testing (54 %) or for those who are geographically constrained (60 %). The authors concluded there is a general lack of confidence among genetic health professionals around interpreting DTC-GT results but suggested that confidence might increase over time as professionals gain more experience.

Discussion

The past few years have seen a modest yet notable amount of empirical studies focused on DTC-GT. Findings from this research begin to shed light on the various questions that have been raised regarding this controversial approach to personal genomics. One area of interest has been the ways in which DTC-GT services are marketed to consumers. Our review of the limited data evaluating DTC-GT companies' "product descriptions" reinforce concerns raised by commentators about the potential for customers to be misled about the benefits versus risks and limitations of test services. For example, that almost two-thirds of companies reviewed neglected to note any risks of testing is particularly concerning. However, it should be noted that the companies reviewed represent a very heterogeneous group, and that the most commonly used sites do in fact disclose potential psychological and social risks of learning personal genetic information. Nevertheless, it would be naïve to expect a truly balanced, nuanced view of testing from any company's promotional materials, such that public education from disinterested third parties would seem appropriate [9]. Concerns about "truth in advertising" of health-related products are not unique to this industry; moving forward, lessons might be taken from prior regulation debates involving over-the-counter nutriceuticals and DTC advertising of prescription medications [40].

Studies suggest that public awareness of DTC-GT within the US has steadily increased in recent years. This is not a surprising finding given the high-profile media coverage that the industry has received, including news stories across such diverse outlets as *Time* magazine, the *New York Times*, and NBC's *Today* show [1, 41, 42]. Also as would be expected, awareness varies by demographic groups and family history of various medical conditions. The prototypical consumer appears to be a white, well-educated, middle-aged professional, with various reasons for pursuing DTC-GT services. Many are health-focused, but others are more generally curious about their genetics and in tracing their ancestral history. Some companies bundle very different types of genetic information (health risk, carrier status, medication response, ancestry) within a single service, appealing to the wide range of motivations people seem to have in learning about aspects of their own genetic profile. These motivations are also a reminder that consumers often have a much different view of the benefits of test results than do expert commentators and health care professionals. The latter tend to view genetic testing through the lens of clinical utility, where findings are seen as valuable to the extent that they possess predictive value and/or inform proven medical care options. However, consumers interested in DTC-GT results may find personal utility in satisfying curiosity and in feeding a general sense that "knowledge is power." Although test interest may well be driven by a fascination with what Nelkin has termed the "DNA mystique," many individuals who seek DTC-GT results may possess complex, meaningful rationales for testing that need not be dismissed as irrational or frivolous [43].

Legitimate concerns, however, have been raised that individuals who purchase DTC-GT services may not fully comprehend the risk information that they receive [44]. Available studies do not support the notion that laypersons will be given to gross misunderstandings of their test results, such as believing that "genetics is destiny" with regard to risk of common diseases. Indeed, several studies reviewed here suggest that most participants will be able to take home the "gist" of test result information, even

without professional assistance. However, these same studies also suggest some biases and misinterpretations of the nuances of test results, including difficulties in interpreting complex numerical information and a tendency to overrate the clinical benefits of test results. Interestingly, some data suggested that consumers may also overrate their own ability to make sense of test results, which may help explain why they are not likely to consult health professionals for assistance with test interpretation, even when those (e.g., genetic counselors via telephone) are readily available.

The findings on the psychological impact of DTC testing are consistent with research findings on genetic testing in general: namely, that catastrophic reactions are very rare and that test recipients tend to adjust adequately to risk information [45]. Given that the vast majority of genetic markers tested for by DTC companies are low penetrance alleles with modest associated attributable risk, it is not surprising that the modal reaction may be, in the words of Caulfield, "more of a shrug than a shriek" (p. 24) [46]. The case report on *BRCA* testing from Dohany et al. [32] however, reminds us that not all responses to test information are benign. Given the importance of expectations in determining emotional reactions to almost any life event, clinically significant findings that are completely unanticipated (akin to "incidentalomas" in medical testing) would seem to be the most likely type of result to induce distress. As the capabilities and uses of whole-genome sequencing increase, we may well need to "expect the unexpected" with regard to results that are not well-considered upon initiation of testing. One protection against harms here may be use of tiered consent processes, where test recipients are asked in discrete steps to consider and make choices about the different types of information they would and would not be interested in receiving [47]. Some companies have attempted to employ this type of process in their services. 23andMe, for example, does not provide immediate access to *BRCA* results or risk of Alzheimer's disease when returning results to its customers; they are asked instead to read through additional information on the benefits, risks and limitations of testing in these contexts before being given an option to "unlock" their results. However, it is unclear whether online users engage in the type of "cooling off" processes (i.e., taking significant time between learning about and receiving test findings to prepare emotionally and decide whether or not one truly wishes to learn one's results) that would be enforced in genetic counseling models for conditions like Huntington's disease [48].

Of course, results that evoke significant emotional distress may nevertheless be of medical benefit to genetic test recipients and their family members. This point is underscored by the Francke et al. [33•] report that noted the identification of numerous *BRCA* mutation carriers via DTC-GT services. These are women who may not have been identified in the health care system, given the evidence that more referrals for genetic services should be occurring among women with high risk of *BRCA* mutations [49]. In this instance, many cases of breast cancer were either detected early or likely prevented via risk-reducing surgeries. The evidence for DTC-GT as an overall disease prevention tool, however, is quite minimal. Although some studies reviewed here suggest positive health behavior changes in response to DTC-GT information, the research in this area is plagued by design flaws, including lack of comparison groups or well-validated outcomes measures. The most rigorous study in this area suggested no improvement over baseline among DTC-GT recipients in terms of diet and physical activity [30••], a finding consistent with the broader literature on health behavior changes in response to genetic risk information [50]. Indeed, genetic risk information, whether delivered via DTC or other formats, is unlikely to be a "magic bullet" in the difficult work of promoting behaviors such as healthy eating, sustained and regular physical activity, and smoking cessation.

There is also not much evidence at present that DTC-GT results prompt notable changes in terms of health care utilization. Although extant studies suggest that roughly a quarter of test recipients do in fact share their results with their PCP or other health professionals, significant post-test changes have not have been observed in terms of number of physician visits or use of screening tests and other medical procedures. It is difficult to draw definitive conclusions in this area given the limited number of studies and the fact that personalized genetic information is still in the early stages of diffusion into the lay public. But concerns about provision of DTC-GT leading to 'overtreatment' and undue burdening of PCPs [51] are not well-supported by the current literature. On the other hand, there is also presently no evidence that DTC-GT results generate more appropriately tailored use of proven tools for screening and early detection of common diseases.

Professional organizations representing clinical genetics providers and other health professionals have expressed significant reservations about DTC-GT, and findings from surveys of providers in the field echo many of these concerns. Many PCPs and genetics specialists express doubt not only about the clinical utility of this approach, but also about their own ability to help consumers accurately interpret test results [52]. However, some genetic counselors believe that DTC-GT can be appropriate in certain circumstances, particularly if it is conducted to address

disparities in access to genetic testing (e.g., among rural populations) and followed up with counseling and education by telephone. Genetic counselors occupy an interesting niche in the DTC-GT space, playing numerous roles at once: industry critics, researchers in the field, counselors of consumers, and company service providers. This group may be uniquely positioned to advance the debate on DTC-GT services moving forward.

Directions for Future Research

The DTC-GT literature reflects the relatively short time in which major DTC companies have been operating, as well as the challenges involved for social and behavioral scientists in assessing consumer responses to this fast-changing industry. Some early industry leaders (e.g., deCODEme, Navigenics) no longer offer test services, while others have undergone dramatic changes in their business models. Even those who have been consistent in providing services in a DTC format have significantly reduced prices, increased numbers and types of genetic information, and added supplementary services (e.g., telephone access to genetic counseling). The "moving target" nature of the industry does not mesh well with the deliberate pace of the academic review process for grants and publications. As a result, many of the studies noted here reference responses to test services that may be outdated even before the findings are published.

From a methodological standpoint, the literature can be critiqued on numerous fronts. For example, there has been an overreliance on descriptive (versus hypothesis-driven), atheoretical studies, use of convenience samples, and mock testing scenarios. Although well-controlled experimental designs can be useful in illuminating psychological and cognitive processes in response to different types of test information, there is no substitute for the "real thing" when trying to understand how people will react to DTC-GT. The genetic testing literature has long demonstrated an incongruence in hypothetical versus actual responses to testing (e.g., at-risk individuals' intentions to seek testing for Huntington's disease far outstripped uptake rates once testing became available) [53]. The affective forecasting literature from psychology also suggests a general tendency for people to overrate the intensity and duration of their emotional reactions to future events, which would include receiving genetic risk information for a variety of health conditions [54].

Given these limitations, future research is needed across all the domains described above. Such studies would benefit from designs that are prospective in nature, involve longitudinal follow-up and use of appropriate comparison groups, and access to more representative samples. Also welcome would be a focus on family-level responses and decision making [55]; despite the implications of genetic information for family members, relatively few studies have examined in detail how families (versus individuals) are impacted by the provision of DTC-GT results.

Researchers have not typically had access to consumers' own individual test results, hampering assessment of laypersons' comprehension of their own results (e.g., accuracy of risk perceptions) and understanding of their implications. One ongoing study, the NIH-funded Impact of Personal Genomics (PGen) Study [56], is attempting to address this gap in its examination of consumers' responses to their personal DTC-GT results (full disclosure: the lead author is joint Principal Investigator on this project). The study has enrolled over 1,800 customers of two leading personal genomics companies who are followed over time to examine motivations and attitudes toward testing, understanding of their own results, and psychological and behavioral impact of test information.

Conclusions

In sum, the DTC-GT research to date provides support neither for the doomsday scenarios of industry critics nor the naïve optimism of its proponents. Given the current lack of evidence for either dramatic harms or widespread health benefits associated with DTC-GT, one may be excused for concluding that the charged policy debates of the past years have been a bit of a 'tempest in a spit cup.' Of course, the DTC-GT landscape may change as the research in this area matures and the service delivery models in the field evolve. In the meantime, we should resist temptations to make sweeping generalizations about a heterogeneous industry and seek more a systematic, nuanced understanding of the benefits, risks and limitations of the DTC-GT approach.

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Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Appendix

See Table 1.

Table 1 Empirical articles in sample ($N = 39$)

Author	Journal	Method/sample[a]	Findings[a]
Content analyses of websites			
Arribas-Ayllon et al. [12]	Commun Med	We examine the web sites of three personal genomics companies—Navigenics, deCODEme and 23andMe—each of which represents contrasting registers of 'personalisation'	We identify three distinctive registers in these websites: a paternalistic (medical) register; a translational (scientific) register and a democratic (consumerist) register. We explore in detail the rhetorical and discourse devices employed in these websites to assess how personalised health care is promised to the public. Promising information that will empower prevention of common complex diseases and ensure better quality of life is conflated with promising greater access to personal information. The presence and absence of scientific legitimacy is related to concerns about accuracy and validity on the one side, and fears of paternalism and elitism on the other. Nevertheless, a common strategy uniting these different styles of personalisation is consumer empowerment
Harris et al. [13]	J Genet Couns	We offer a discourse analysis of ways in which genetic counseling is represented on DTC GT websites, blogs and other online material	This analysis identified four types of genetic counseling represented on the websites: the integrated counseling product; discretionary counseling; independent counseling; and product advice. Genetic counselors are represented as having the following roles: genetics educator; mediator; lifestyle advisor; risk interpreter; and entrepreneur. We conclude that genetic counseling as represented on DTC GT websites demonstrates shifting professional roles and forms of expertise in genetic counseling. Genetic counselors are also playing an important part in how the genetic testing market is taking shape
Lynch et al. [57]	J Genet Couns	The purpose of this study was to determine and assess the themes presented by U.S. news media regarding DTC genetic testing. We performed a Lexis-Nexis search with the keywords "Direct-to-Consumer" and "genetic test" for news stories published from 2006–2009. Ninety-two news stories were included	Stories displayed moderate genetic determinism and were neutral about validity and utility. Stories indicated that insurance and employers were the most likely sources of discrimination, yet identified the physicians and DTC companies as groups most likely to violate privacy. Stories claimed lack of regulation would harm consumers, but most post-GINA stories did not discuss the law. The costs of tests were frequently included
Singleton et al. [11]	J Genet Couns	To understand the information that potential consumers of DTCGT services are exposed to on company websites, we conducted a content analysis of 23 health-related DTCGT websites	Results revealed that benefit statements outweighed risk and limitation statements 6–1. The most frequently described benefits were: (1) disease prevention, (2) consumer education, (3) personalized medical recommendations, and (4) the ability to make health decisions. Thirty-five percent of websites also presented at least one risk of testing. Seventy-eight percent of websites mentioned at least one limitation of testing. Based on this information, potential consumers might get an inaccurate picture of genetic testing which could impact their ability to make an informed decision
Wagner et al. [58]	Genet Med	To promote a data-driven discussion of the DNA ancestry testing industry, we conducted a systematic investigation to identify companies selling DNA ancestry tests and conducted an empirical study of the industry's practices using data collected from each company's website	We present a wealth of data, including an updated directory of companies, marketing slogans, product types and names, range of prices, diversity of reporting and representing results, noted benefits and limitations of testing, and a host of website practices

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
User attitudes, motivations, intentions			
Finney Rutton et al. [14]	J Cancer Epidemiol	We analyzed nationally representative, cross-sectional data from the Health Information National Trends Survey in 2008 (n = 7, 674) and 2011 (n = 3, 959) to assess population-level changes in awareness of DTC genetic testing in the U.S. and to explore sociodemographic, health care, Internet use, and population density correlates	Overall, awareness increased significantly from 29 % in 2008 to 37 % in 2011. The observed increase in awareness from 2008 to 2011 remained significant (OR = 1.39) even when adjusted for sociodemographic variables, health care access, Internet use, and population density. Independent of survey year, the odds of awareness of DTC genetic tests were significantly higher for those aged 50–64 (OR = 1.64), and 65–74 (OR = 1.60); college graduates (OR = 2.02); those with a regular source of health care (OR = 1.27); those with a prior cancer diagnosis (OR = 1.24); those who use the Internet (OR = 1.27); and those living in urban areas (OR = 1.25). Surveillance of awareness—along with empirical data on use of and response to genetic risk information—can inform public health and policy efforts to maximize benefits and minimize risks of DTC genetic testing
Gollust et al. [19]	Public Health Genomics	Early adopters of personal genomics were surveyed to assess their motivations, perceptions and intentions. Participants completed an Internet-based survey about their motivations, awareness of personalized medicine, perceptions of study risks and benefits, and intentions to share results with health care providers	Respondents were motivated to participate for their own curiosity and to find out their disease risk to improve their health. Fewer than 10 % expressed deterministic perspectives about genetic risk, but 32 % had misperceptions about the research study or personal genomic testing. Most respondents perceived the study to have health-related benefits. Nearly all (92 %) intended to share their results with physicians, primarily to request specific medical recommendations
Gordon et al. [24]	J Genet Couns	We conducted semistructured interviews with 60 adults participating in the Coriell Personalized Medicine Collaborative. The interviews took place after receiving results providing genomic and other risk information for up to eight common complex diseases	We found that participants were most likely to recall results which conferred an increased risk or those of particular personal interest. Participants understood the multi-factorial nature of common complex disease, and generally did not have negative emotional responses or overly deterministic perceptions of their results. Although most participants expressed a desire to use results to improve their health, a minority had actually taken action (behavior change or shared results with their doctor) at the time of the interview
Gray et al. [21]	Clin Genet	We conducted a randomized experiment; women viewed a 'mock' *BRCA* testing website without [control group (CG)] or with information on the potential risks of DTC testing [RG; framed two ways: unattributed risk (UR) information and risk information presented by experts (ER)]. Seven hundred and sixty-seven women participated	Women in the RG had less positive beliefs about DTC testing (mean RG = 23.8,CG = 25.2; p = 0.001), lower intentions to get tested (RG = 2.8,CG = 3.1; p = 0.03), were more likely to prefer clinic-based testing (RG = 5.1,CG = 4.8; p = 0.03) and to report that they had seen enough risk information (RG = 5.3,CG = 4.7; p < 0.001). UR and ER exposure produced similar effects. Effects did not differ for women with or without a personal/family history of breast/ovarian cancer. Exposing women to the potential risks of DTC *BRCA* testing altered their beliefs, preferences, and intentions

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
Hall et al. [15]	Genet Test Mol Biomarkers	To determine if awareness of, interest in, and use of direct-to-consumer (DTC) genetic testing is greater in a sample of high-risk individuals (cancer cases and their relatives), compared to controls. A survey was mailed to participants to assess DTC genetic testing awareness, interest and use. Sample of 1,267 participants	Forty-nine percent of respondents were aware of DTC genetic testing. Of those aware, 19 % indicated interest in obtaining and <1 % reported having used DTC genetic testing. Additional information supplied by respondents who reported use of DTC genetic tests indicated that 55 % of these respondents likely engaged in clinical genetic testing, rather than DTC genetic testing. Awareness of DTC genetic testing was greater in our sample of high-risk individuals than in controls and population-based studies
Kolor et al. [16]	Genet Med	We assessed awareness and use of direct-to-consumer personal genomic tests in Connecticut, Michigan, Oregon, and Utah using the 2009 Behavioral Risk Factor Surveillance System and compared the state results to the 2008 national HealthStyles survey results	Awareness was the highest in Oregon (29.1 %) and the lowest in Michigan (15.8 %). Factors associated with awareness across all states and nationally were higher education, higher income, and increasing age, except among those 75 years or older. Less than 1 % of respondents had used the tests, with about one-half to three-quarters of those sharing the results with a health-care provider
Langford et al. [18]	J Genet Couns	To examine the association of 1) race/ethnicity and 2) numeracy with awareness of DTC genetic tests. Secondary analysis of 6,754 Hispanic, black, and white adult respondents to the National Cancer Institute's 2007 Health Information National Trends Survey (HINTS)	After controlling for sociodemographic variables, black respondents were significantly less likely to have heard of DTC genetic tests compared to white respondents (OR00.79; CI: 0.65–0.97). When numeracy variables were added to the model, the effect of black race was no longer significant (OR00.84; CI: 0.69–1.04). Hispanic respondents did not significantly differ from white respondents in awareness of DTC genetic tests. Other significant correlates of DTC genetic tests awareness in the full model included education, income, age, and numeracy variables including degree to which people use medical statistics and numbers to make health decisions, and preference for words or numbers when discussing "the chance of something happening"
Leighton et al. [26]	Public Health Genomics	An online survey was posted on Facebook that included questions relating to 4 sample test results for risk of developing colorectal cancer, heart disease and skin cancer. Genetic counselors were used as a comparison group. 145 individuals from the general public and 171 genetic counselors completed the survey	A significant difference was found between the way the general public and genetic counselors interpreted the meaning of the DTC results. The general public respondents also believed that results in all four scenarios would be significantly more helpful than the genetic counselors did. Although the majority of general public respondents rated the results as easy to understand, they often misinterpreted them
Ormond et al. [59]	Genet Med	Purpose: To assess knowledge, attitudes and beliefs of students toward personal genomics as it related to themselves as both customers and future physicians. We surveyed first-year medical students and graduate students before and after a core genetics course	After the course, students were less likely to believe that genotyping information would be useful to physicians, patients, or consumers; genotyping would provide information to improve their own personal health; or personal genomic testing services are diagnostic of medical conditions. They were more likely to answer knowledge questions accurately after the course but still had difficulty with clinical interpretation. Despite these changes, a slight majority of students were, and remained, interested in undergoing genotyping themselves. Of note, the number who believed genotyping "would help them understand genetic concepts better than someone else's data" decreased. General curiosity was the most commonly chosen reason for interest in undergoing genotyping, and approximately 50 % of respondents expressed concern about confidentiality of results

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
Ortiz et al. [17]	Prev Chronic Dis	We analyzed data from adults aged 18 years or older who completed information on genetic test awareness (n = 611; 96 % of study population) from the Health Information National Trends Survey conducted in Puerto Rico in 2009	The majority of respondents (56 %) were aware of direct-to-consumer genetic tests, and approximately 4 % had ever undergone any genetic test. Respondents who had never been married were less likely to be aware of DTC tests, as were current smokers. Respondents who ever sought cancer information were more likely to be aware of these tests
Perez et al. [60]	J Health Commun	This study examined attitudes toward direct-to-consumer advertising (DTCA) and online testing for *BRCA* among 84 women at a high-risk clinic as well as additional factors that may be associated with these attitudes, such as personal and familial cancer history, cancer worry and risk perception, and history with genetic testing = counseling	Results showed that the majority of the women held favorable attitudes toward DTCA for *BRCA* testing but did not support online testing. Factors such as familial ovarian cancer, cancer worry, and satisfaction with genetic counseling = testing were associated with positive attitudes toward DTCA, whereas personal breast cancer history was related to negative attitudes
Rahm et al. [61]	J Genet Couns	Purpose: To determine possible attitudes toward and understanding of direct-to-consumer (DTC) genetic testing among members of a large managed care organization, and whether differences might exist between population groups. Ten focus groups were conducted by population type (high risk, White, African American, Hispanic/Latino) to determine knowledge, attitudes and beliefs about DTC genetics	Participants framed the issue mainly in terms of disease prevention and uncertainty of reaction to results, with some variation between population types. The concept of an "Informed Consumer," or process to seek information when the issue becomes personally relevant, emerged. This concept suggests that individuals may seek additional assistance to make personally-appropriate choices when faced with a DTC advertisement or genetic test
Roberts et al. [62]	J Genet Couns	We are reporting what we believe to be the first published case of patient initiated direct to consumer (DTC) genetic testing to test for the presence of a known familial mutation	This case shows that patients are still fearful of genetic discrimination, despite the passage of the Genetic Information Nondiscrimination Act (GINA), and that DTC genetic testing may be useful despite the overall negative feeling towards this type of testing in the genetic counseling community
Su et al. [20]	J Community Genet	We conducted an exploratory study based on users' personal stories. Qualitative content analysis of users' personal stories found on Internet blogs and DTC genetic testing companies' websites	We identified five major sets of motivations and expectations towards DTC genome-wide testing. These themes are related to (1) health, (2) curiosity and fascination, (3) genealogy, (4) contributing to research, and (5) recreation
Sweeny and Legg [22]	Psychol Health	This study is one of the first to examine predictors of interest in DTC genetic testing. Participants read one of the three types of information about DTC genetic testing (positive only, negative only or both) and reported perceptions of and intentions to pursue testing	People who read both positive and negative information did not differ from people who read only negative information in their intentions to pursue testing. Our findings provide further confirmation of the role of perceived benefits, perceived barriers and anticipated regret in health decision-making

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
Vayena et al. [63]	Public Health Genomics	This study explores attitudes, motivations and self-reported impact in connection with direct-to-consumer (DTC) genomic testing amongst a group of life scientists in Switzerland. Data were collected through: (1) a self-completion online questionnaire, and (2) semi-structured qualitative interviews. Forty participants completed the questionnaire and ten were interviewed	Curiosity was mentioned as the primary reason for undergoing testing, while less significance was attributed to receiving actionable health information. The opportunity to contribute to research ranked high as a motive for testing. Overall, participants assessed their experience with the test as positive and were willing to recommend it to others. Some reported that the testing had an impact on how they view their health, but only a third of participants planned on showing the results to health practitioners. Participants consistently referred to 'fun' when describing several aspects of the testing experience. The 'fun factor' manifested itself in different phases of the process, including the motivation for taking the test, receiving the information and putting the test results to use (including sharing and discussing it with others). This finding suggests the need to further explore the concept of personal utility in DTC genomics
Psychological/health behavior impact			
Bansback et al. [28]	Genet Test Mol Biomarkers	A web-based survey presented 12 hypothetical genetic risk profiles for four diseases; 319 participants (69 %) completed 3,828 unique genetic risk profiles	Across all profiles, most participants anticipated making doctor's appointments (63 %), lifestyle changes (57 %), and accessing screening (57 %); 40 % anticipated feeling more worried and anxious. Preliminary results suggest that genetic information may increase worry/anxiousness and health-seeking behaviors among consumers of DTC tests
Bloss et al. [30]	N Engl J Med	We recruited subjects from health and technology companies who elected to purchase the Health Compass at a discounted rate. Subjects reported any changes in symptoms of anxiety, intake of dietary fat, and exercise behavior at a mean (±SD) of 5.6 ± 2.4 months after testing, as compared with baseline, along with any test-related distress and the use of health-screening tests. From a cohort of 3,639 enrolled subjects, 2,037 completed follow-up	Primary analyses showed no significant differences between baseline and follow-up in anxiety symptoms ($p = 0.80$), dietary fat intake ($p = 0.89$), or exercise behavior ($p = 0.61$). Secondary analyses revealed that test-related distress was positively correlated with the average estimated lifetime risk among all the assessed conditions ($\beta = 0.117$, $p < 0.001$). However, 90.3 % of subjects who completed follow-up had scores indicating no test-related distress. There was no significant increase in the rate of use of screening tests associated with genomewide profiling, most of which are not considered appropriate for screening asymptomatic persons in any case
Corpas [64]	J Genet Couns	This article presents a personal journey of a closeknit family from Málaga, Spain who engaged with direct-to-consumer (DTC) genomic testing. A thoughtful account, written in the first person, is offered on the experience of genome testing across the various members of the family together with a reflection on how it felt to be a custodian of the 'family genome'	The way the family processed their genome information is explored and the difficulties and challenges that resulted are discussed. Whilst there is a wealth of literature that describes how families communicate information surrounding single genes, there is very little which explores the experience of communication about whole, shared genomes

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
Dar-Nimrod et al. [29]	Genet Med	Participants were led to believe that they had entered a study on the genetics of alcoholism and sleep disorders. Participants provided a saliva sample purportedly to be tested for the presence of relevant genes. While awaiting the results, they completed a questionnaire assessing their emotional state. They subsequently received a bogus report about their genetic susceptibility and completed a questionnaire about their emotional state and items assessing perceived control over drinking, relevant future drinking-related intentions, and intervention-related motivation and behavior	Participants who were led to believe that they had a gene associated with alcoholism showed an increase in negative affect, decrease in positive affect, and reduced perceived personal control over drinking. Reported intentions for alcohol consumption in the near future were not affected; however, individuals were more likely to enroll in a "responsible drinking" workshop after learning of their alleged genetic susceptibility
Dohany et al. [32]	J Genet Couns	Reports a case of a client who discovered she had a *BRCA* mutation following direct-to-consumer (DTC) genetic testing in the absence of genetic counseling	Significant psychological distress and confusion can occur as a result of DTC genetic testing for highly penetrant single gene disorders. Pre- and post-test genetic counseling in conjunction with DTC genetic testing may alleviate consumers' distress and empower clients to proactively utilize their result information
Egglestone et al. [31]	J Genet Couns	An online survey was conducted (n = 275). Respondents were composed of individuals who had purchased a DTC genetic test and received their results (consumers, n = 189), as well as individuals who were either awaiting test results or considering purchasing a test (potential consumers, n = 86). Consumers were asked if their health behaviour or health anxiety had changed after receiving their results	In total, 27.3 % of consumers claimed a change in health behaviour, all either positive or neutral, with no reported cessation of any existing health behaviour. A change in health anxiety was claimed by 24.6 % of consumers, 85.3 % of which were a reduction. Consumers had significantly better health behaviour scores than potential consumers ($p = 0.02$), with no significant difference in health anxiety
Francke et al. [33]	PeerJ	To assess and quantify emotional and behavioral reactions of consumers to their 23andMe Personal Genome Service report of three *BRCA* mutations that are common in Ashkenazi Jews, we invited all 136 *BRCA1* and *BRCA2* mutation-positive individuals in the 23andMe customer database who had chosen to view their *BRCA* reports to participate in this IRB-approved study. We also invited 160 mutation negative customers who were matched for age, sex and ancestry. Semi-structured phone interviews were completed for 32 mutation carriers, 16 women and 16 men, and 31 non-carriers	Eleven women and 14 men had received the unexpected result that they are carriers of a *BRCA1* 185delAG or 5382insC, or *BRCA2* 6174delT mutation. None of them reported extreme anxiety and four experienced moderate anxiety that was transitory. Remarkably, five women and six men described their response as neutral. Most carrier women sought medical advice and four underwent risk-reducing procedures after confirmatory mutation testing. Male carriers realized that their test results implied genetic risk for female relatives, and several of them felt considerably burdened by this fact. Sharing mutation information with family members led to screening of at least 30 relatives and identification of 13 additional carriers. Non-carriers did not report inappropriate actions, such as foregoing cancer screening. All but one of the 32 mutation-positive participants appreciated learning their *BRCA* mutation status

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
James et al. [27]	Mayo Clin Proc	Patients attending a preventive medicine clinic were randomly assigned to receive either genomic risk information from a DTC product plus usual care (n = 74) or usual care alone (n = 76), 150 patients agreed to participate	Compared with those receiving usual care, participants who received genomic risk information initially rated their risk as higher for four conditions [abdominal aneurysm (p = 0.001), Graves disease (p = 0.04), obesity (p = 0.01), and osteoarthritis (p = 0.04)] and lower for one [prostate cancer (p = 0.02)]. Although differences were not significant, they also reported higher levels of worry for seven conditions and lower levels for five others. At 1 year, there were no significant differences between groups
Kaufman et al. [25]	J Genet Couns	Conducted online survey of DTC customers of 23andMe, deCODEme, and Navigenics. Random samples of U.S. DTC customers were invited to participate. Of 3,167 DTC customers invited, 33 % (n = 1,048) completed the survey	Forty-three percent of respondents had sought additional information about a health condition tested; 28 % had discussed their results with a health care professional; and 9 % had followed up with additional lab tests. Sixteen percent of respondents had changed a medication or supplement regimen, and one third said they were being more careful about their diet. Many of these health-related behaviors were significantly associated with responses to a question that asked how participants would perceive their colon cancer risk (as low, moderate, or high) if they received a test result showing an 11 % lifetime risk, as compared to 5 % risk in the general population
Health care impact/sharing results with providers			
Austin and Hegele [65]	Can J Cardiol	Information to guide physicians and patients on how to react clinically to direct-to-consumer (DTC) genetic testing for cardiovascular disease (CVD) is scarce. We discuss selected results and interpretation of this testing, and the outcome of subsequent lifestyle interventions that proved central to the management of one patient. We report the case of a 52-year-old man with a family history of CVD who had DTC genetic testing performed	We discuss selected results and interpretation of this testing and the outcome of subsequent lifestyle interventions. Despite the information this new technology seemed to provide, traditional advice on lifestyle modification was central to his management
Kaphingst et al. [23]	Genet Med	This study examined patients' recall and interpretation of, and responses to, genetic susceptibility test results provided directly by mail. This observational study had three prospective assessments (before testing, 10 days after receiving results, and 3 months later). Participants were 199 patients aged 25–40 years who received free genetic susceptibility testing for eight common health conditions	More than 80 % of the patients correctly recalled their results for the eight health conditions. Patients were unlikely to interpret genetic results as deterministic of health outcomes (mean = 6.0, s.d. = 0.8 on a scale of 1–7, 1 indicating strongly deterministic). In multivariate analysis, patients with the least deterministic interpretations were white (p = 0.0098), more educated (p = 0.0093), and least confused by results (p = 0.001). Only 1 % talked about their results with a provider. Findings suggest that most patients will correctly recall their results and will not interpret genetics as the sole cause of diseases. The subset of those confused by results could benefit from consultation with a health-care provider, which could emphasize that health habits currently are the best predictors of risk. Providers could leverage patients' interest in genetic tests to encourage behavior changes to reduce disease risk

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
Reid et al. [35]	Genet Med	The objective of this work was to examine whether offers of multiplex genetic testing increase health-care utilization among healthy patients aged 25–40 years. A total of 1,599 continuously insured adults aged 25–40 years were surveyed and offered a multiplex genetic susceptibility test for eight common health conditions	In the pretest period, persons choosing genetic testing used an average of 1.02 physician visits per quarter as compared with 0.93 and 0.82 for the baseline-only and Web-only groups, respectively ($p < 0.05$). There were no statistically significant differences by group in the pretest use of any common medical tests or procedures associated with four common health conditions. When changes in physician and medical test/procedure use in the posttest period were compared among the groups, no statistically significant differences were observed for any utilization category
Saunders et al. [66]	Hered Cancer Clin Pract	We describe an Ashkenazi Jewish patient who illustrates that current testing criteria are too restrictive, particularly for this population of patients. The patient's sister was diagnosed with breast cancer at age 33; however, she was not a mutation carrier. Based on practice guidelines, the patient was not recommended genetic testing. She subsequently underwent direct-to-consumer (DTC) testing and discovered that she was a mutation carrier	This case demonstrates the need for clinicians to be aware of the higher prevalence of *BRCA* mutations in the Ashkenazi population. It also exemplifies the need to involve medical professionals, including genetic counselors, in the dissemination of DNA test results
Sturm and Manickam [67]	J Genet Couns	We present an in-depth case study of an individual who ordered DTC genetic testing and subsequently sought genetic counseling	This case presents a unique learning experience for the field of genomic counseling, as the patient did not fit the typical assumptions regarding 'early adopters' of DTC testing. It also allowed the genetics health care providers involved in the case to identify gaps in current genetic counseling practice that need to be filled and approaches to employ for successful delivery of genomic counseling. Based on our experience, we developed practical recommendations for genomic counseling, which include novel approaches to case preparation, use of electronic tools during the counseling session, and focusing on education as the major component of the genomic counseling session, in order to provide patients with the knowledge necessary to independently interpret and understand large amounts of genomic testing information provided to them
Provider attitudes/experiences			
Brett et al. [39]	Eur J Hum Genet	This study explores genetic health professionals' opinions of health-related DTC-GT and the reported frequency of individuals presenting to clinical genetics services after undertaking testing. Genetic counsellors and clinical geneticists, members of the Human Genetics Society of Australasia, completed an online survey in mid 2011	Nineteen respondents (11 %) reported one or more client(s) referred to them after undertaking DTC-GT. Descriptions of 25 clients were extracted from responses, and respondents reported that all clients were concerned for the health of either themselves or family members. Most clients presented to genetic clinics specifically as a result of their DTC-GT (96 %) and were self or GP referred (92 %). Respondents perceived that their clients typically undertook DTC-GT because they wanted to identify monogenic conditions, including carrier testing and/or know their susceptibility or predisposition for complex conditions (88 %). The majority of clients needed help interpreting DTC-GT results (80 %), however in general were not questioning the validity of their DTC-GT results (92 %) nor seeking further genetic testing (84 %)

Table 1 continued

Author	Journal	Method/sample[a]	Findings[a]
Hock et al. [38]	Genet Med	This study assesses genetic counselors' experience, knowledge, and beliefs regarding direct-to-consumer genetic testing for tests that would currently be offered in genetics clinics. Members of the National Society of Genetic Counselors completed a web-administered survey in February 2008. There were 312 respondents	Eighty-three percent of respondents had two or fewer inquiries about direct-to-consumer genetic testing, and 14 % had received requests for test interpretation or discussion. Respondents believed that genetic counselors have a professional obligation to be knowledgeable about direct-to-consumer genetic testing (55 %) and interpret results (48 %). Fifty-one percent of respondents thought genetic testing should be limited to a clinical setting; 56 % agreed direct-to-consumer genetic testing is acceptable if genetic counseling is provided. More than 70 % of respondents would definitely or possibly consider direct-to-consumer testing for patients who (1) have concerns about genetic discrimination, (2) want anonymous testing, or (3) have geographic constraints
Powell et al. [36]	J Genet Couns	To assess the educational needs of North Carolina primary care physicians (PCPs) about direct-to-consumer (DTC) genetic testing, surveys were mailed to 2,402 family and internal medicine providers in North Carolina	Out of 382 respondents, 323 (85 %) felt unprepared to answer patient questions and 282 (74 %) reported wanting to learn about DTC genetic testing. A total of 148 (39 %) were aware of DTC genetic testing. Among these, 63 (43 %) thought DTC genetic testing was clinically useful. PCPs who felt either unprepared to answer patient questions (OR00.354, p00.01) or that DTC genetic testing was clinically useful (OR05.783, p00.00) were more likely to want to learn about DTC genetic testing. PCPs are interested in learning about DTC genetic testing, but are mostly unaware of DTC testing and feel unprepared to help patients with DTC testing results
Powell et al. [37]	J Genet Couns	The purpose of this study was to assess primary care physicians' awareness, experience, opinions and preparedness to answer patients' questions regarding direct-to-consumer (DTC) genetic testing. An anonymous survey was mailed to 2,402 family and internal medicine providers in North Carolina	An anonymous survey was mailed to 2,402 family and internal medicine providers in North Carolina. Of the 382 respondents, 38.7 % (n = 148) were aware of and 15 % (n = 59) felt prepared to answer questions about DTC genetic tests. Respondents aged 50 or older were more likely to be aware of DTC genetic testing than those less than 40 years old (OR = 2.42). Male providers were more likely to feel prepared to answer questions than female providers (OR = 2.65). Among respondents who reportedly were aware, family practitioners were more likely than internists (OR = 3.30) to think DTC testing was clinically useful, and 18.9 % had patients ask questions or bring in test results

Italics denotes article cited in text

[a] Extracted from authors' abstract

References

Papers of particular interest, published recently, have been highlighted as:

- • Of importance,
- •• Of major importance

1. Hamilton A. Best inventions of 2008. In: time. 2008. http://www.time.com/time/specials/packages/article/0,28804,1852747_1854493_1854113,00.html. Accessed 28 Apr 2013.
2. Yeager A. News 2008. Nature. 2008;2008(456):844–5.
3. Hudson K, Javitt G, Burke W, Byers P. ASHG statement* on direct-to-consumer genetic testing in the United States. Obstet Gynecol. 2007;110:1392–5.
4. American College of Medical Genetics. ACMG Statement on Direct-to-Consumer Genetic Testing. 2008. http://www.acmg.net//AM/Template.cfm?Section=Terms_and_Conditions&termsreturnurl=Section=Policy_Statements&Template=/CM/ContentDisplay.cfm&ContentID=2975. Accessed 28 Apr 2013.
5. 23andMe. 2013. https://www.23andme.com/. Accessed 28 Apr 2013.
6. Allison M. Direct-to-consumer genomics reinvents itself. Nat Biotechnol. 2012;30:1027–9.
7. United States Government Accountability Office. Misleading test results are further complicated by deceptive marketing and other questionable practices. http://www.gao.gov/products/GAO-10-847T. Accessed 28 Apr 2013.
8. Borry P, Van Hellemondt RE, Sprumont D, Jales CFD, Rial-Sebbag E, Spranger TM, Curren L, Kaye J, Nys H, Howard H. Legislation on direct-to-consumer genetic testing in seven European countries. Eur J Hum Genet. 2012;20:715–21.
9. National Society of Genetic Counselors. Position Statements. http://www.nsgc.org/Media/PositionStatements/tabid/330/Default.aspx#DTC. Accessed 28 Apr 2013.
10. Maves MD. Re: molecular and clinical genetics panel of the medical devices advisory committee; notice of meeting [Docket No. FDA-2011-N-0066]. http://www.ama-assn.org/resources/doc/washington/consumer-genetic-testing-letter.pdf. Accessed 28 Apr 2013.
11. Singleton A, Erby LH, Foisie KV, Kaphingst KA. Informed choice in direct-to-consumer genetic testing (DTCGT) websites: a content analysis of benefits, risks, and limitations. J Genet Couns. 2012;21:433–9.
12. Arribas-Ayllon M, Sarangi S, Clarke A. Promissory accounts of personalisation in the commercialisation of genomic knowledge. Commun Med. 2011;8:53–66.
13. Harris A, Kelly SE, Wyatt S. Counseling customers: emerging roles for genetic counselors in the direct-to-consumer genetic testing market. J Genet Couns. 2012;22(2):277–88.
14. Finney Rutten LJ, Gollust SE, Naveed S, Moser RP. Increasing public awareness of direct-to-consumer genetic tests: health care access, Internet use, and population density correlates. J Cancer Epidemiol. 2012;2012:309109.
15. Hall TO, Renz AD, Snapinn KW, Bowen DJ, Edwards KL. Awareness and uptake of direct-to-consumer genetic testing among cancer cases, their relatives, and controls: The Northwest Cancer Genetics Network. Genet Test Mol Biomarkers. 2012;16:744–8.
16. Kolor K, Duquette D, Zlot A, Foland J, Anderson B, Giles R, Wrathall J, Khoury MJ. Public awareness and use of direct-to-consumer personal genomic tests from four state population-based surveys, and implications for clinical and public health practice. Genet Med. 2012;14:860–7.
17. Ortiz AP, López M, Flores LT, Soto-Salgado M, Finney Rutten LJ, Serrano-Rodriguez RA, Hesse BW, Tortolero-Luna G. Awareness of direct-to-consumer genetic tests and use of genetic tests among Puerto Rican adults, 2009. Prev Chronic Dis. 2011;8:A110.
18. Langford AT, Resnicow K, Roberts JS, Zikmund-Fisher BJ. Racial and ethnic differences in direct-to-consumer genetic tests awareness in HINTS 2007: sociodemographic and numeracy correlates. J Genet Couns. 2012;21:440–7.
19. Gollust SE, Gordon ES, Zayac C, Griffin G, Christman MF, Pyeritz RE, Wawak L, Bernhardt BA. Motivations and perceptions of early adopters of personalized genomics: perspectives from research participants. Public Health Genomics. 2012;15:22–30.
20. Su Y, Howard HC, Borry P. Users' motivations to purchase direct-to-consumer genome-wide testing: an exploratory study of personal stories. J Community Genet. 2011;2:135–46.
21. Gray SW, Hornik RC, Schwartz JS, Armstrong K. The impact of risk information exposure on women's beliefs about direct-to-consumer genetic testing for BRCA mutations. Clin Genet. 2012;81:29–37.
22. Sweeny K, Legg AM. Predictors of interest in direct-to-consumer genetic testing. Psychol Health. 2011;26:1259–72.
23. Kaphingst KA, McBride CM, Wade C, Alford SH, Reid R, Larson E, Baxevanis AD, Brody LC. Patients' understanding of and responses to multiplex genetic susceptibility test results. Genet Med. 2012;14:681–7.
24. Gordon ES, Griffin G, Wawak L, Pang H, Gollust SE, Bernhardt BA. "It's not like judgment day": public understanding of and reactions to personalized genomic risk information. J Genet Couns. 2012;21:423–32.
25. • Kaufman DJ, Bollinger JM, Dvoskin RL, Scott JA. Risky business: risk perception and the use of medical services among customers of DTC personal genetic testing. J Genet Couns. 2012;21:413–422. *This article reports on findings from a large online survey (n = 1048) of DTC-GT customers. Results suggest that consumers initiate various health-related behaviors in response to their personal genetic test results and that these actions are correlated with baseline perceptions of health risks.*
26. Leighton JW, Valverde K, Bernhardt BA. The general public's understanding and perception of direct-to-consumer genetic test results. Public Health Genomics. 2012;15:11–21.
27. James KM, Cowl CT, Tilburt JC, Sinicrope PS, Robinson ME, Frimannsdottir KR, Tiedje K, Koenig BA. Impact of direct-to-consumer predictive genomic testing on risk perception and worry among patients receiving routine care in a preventive health clinic. Mayo Clin Proc. 2011;86:933–40.
28. Bansback N, Sizto S, Guh D, Anis AH. The effect of direct-to-consumer genetic tests on anticipated affect and health-seeking behaviors: a pilot survey. Genet Test Mol Biomarkers. 2012;16:1165–71.
29. Dar-Nimrod I, Zuckerman M, Duberstein PR. The effects of learning about one's own genetic susceptibility to alcoholism: a randomized experiment. Genet Med. 2013;15:132–8.
30. •• Bloss CS, Schork NJ, Topol EJ. Effect of direct-to-consumer genomewide profiling to assess disease risk. N Engl J Med. 2011;364:524–534. *This article reports on findings from a longitudinal study of over 2,000 individuals who received DTC-GT test results. Findings suggest little evidence of adverse psychological reactions to test results and no increase from baseline in health behaviors (e.g., physical activity, dietary fat intake) or screening.*
31. Egglestone C, Morris A, O'Brien A. Effect of direct-to-consumer genetic tests on health behaviour and anxiety: a survey of consumers and potential consumers. J Genet Couns. 2013;. doi: 10.1007/s10897-013-9582-6.
32. Dohany L, Gustafson S, Ducaine W, Zakalik D. Psychological distress with direct-to-consumer genetic testing: a case report of

an unexpected BRCA positive test result. J Genet Couns. 2012;21:399–401.
33. • Francke U, Dijamco C, Kiefer AK, Eriksson N, Moiseff B, Tung JY, Mountain JL. Dealing with the unexpected: Consumer responses to direct-access BRCA mutation testing. PeerJ. 2013;1:e8. *This report from 23andMe investigators details the experiences of consumers who learned from DTC-GT that they were positive for a BRCA mutation. Findings suggest that these unexpected results led in certain cases to risk reduction surgeries and identification of other high-risk family members.*
34. Bloss CS, Wineinger NE, Darst BF, Schork NJ, Topol EJ. Impact of direct-to-consumer genomic testing at long term follow-up. J Med Genet. 2013;50:393–400.
35. • Reid RJ, McBride CM, Alford SH, Price C, Baxevanis AD, Brody LC, Larson EB. Association between health-service use and multiplex genetic testing. Genet Med. 2012;14:852–859. *This study of Multiplex Initiative participants suggests that receipt of multiplex genetic test results does not result in a significant increase from baseline in terms of participants' health service utilization.*
36. Powell KP, Christianson CA, Cogswell WA, Dave G, Verma A, Eubanks S, Henrich VC. Educational needs of primary care physicians regarding direct-to-consumer genetic testing. J Genet Couns. 2012;21:469–78.
37. Powell KP, Cogswell WA, Christianson CA, Dave G, Verma A, Eubanks S, Henrich VC. Primary care physicians' awareness, experience and opinions of direct-to-consumer genetic testing. J Genet Couns. 2012;21:113–26.
38. Hock KT, Christensen KD, Yashar BM, Roberts JS, Gollust SE, Uhlmann WR. Direct-to-consumer genetic testing: an assessment of genetic counselors' knowledge and beliefs. Genet Med. 2011;13:325–32.
39. Brett GR, Metcalfe SA, Amor DJ, Halliday JL. An exploration of genetic health professionals' experience with direct-to-consumer genetic testing in their clinical practice. Eur J Hum Genet. 2012;20:825–30.
40. Frosch DL, Grande D, Tarn DM, Kravitz RL. A decade of controversy: balancing policy with evidence in the regulation of prescription drug advertising. Am J Public Health. 2010;100:24–32.
41. Pinker S. My genome, my self. In: New York Times. 2009. http://www.nytimes.com/2009/01/11/magazine/11Genome-t.html?pagewanted=all&_r=0. Accessed 28 Apr 2013.
42. NBC. The today show. http://www.nbcnews.com/id/21134540/vp/23627696#23627696. Accessed 28 Apr 2013.
43. Nelkin D, Lindee MS. The DNA mystique: the gene as a cultural icon. Ann Arbor: University of Michigan Press; 2004.
44. Frueh F, Greely H, Green R. The future of direct-to-consumer clinical genetic tests. Nat Rev. 2011;12:511–5.
45. Broadstock M, Michie S, Marteau T. Psychological consequences of predictive genetic testing: a systematic review. Eur J Hum Genet. 2000;8:731–8.
46. Caulfield T. Direct-to-consumer testing: if consumers are not anxious, why are policymakers? Hum Genet. 2011;130:23–5.
47. Bunnik EM, Janssens AC, Schermer MH. A tiered-layered-staged model for informed consent in personal genome testing. Eur J Hum Genet. 2012;21(6):596–601.
48. Macleod R, Tibben A, Frontali M, Evers-Kiebooms G, Jones A, Martinez-Descales A, Roos R. Recommendations for the predictive genetic test in Huntington's disease. Clin Genet. 2013;83:221–31.
49. Cox SL, Zlot AI, Silvey K, Elliott D, Horn T, Johnson A, Leman RF. Patterns of cancer genetic testing: a randomized survey of Oregon clinicians. J Cancer Epidemiol. 2012;2012:1–11.
50. Marteau TM, French DP, Griffin SJ, Prevost AT, Sutton S, Watkinson C, Attwood S, Hollands GJ. Effects of communicating DNA-based disease risk estimates on risk-reducing behaviours. Cochrane Database Syst Rev. 2010;6(10):CD007275.
51. McGuire AL, Burke W. An unwelcome side effect of direct-to-consumer personal genome testing: raiding the medical commons. JAMA. 2008;300:2669–71.
52. Nippert I, Harris HJ, Julian-Reynier C, et al. Confidence of primary care physicians in their ability to carry out basic medical genetic tasks-a European survey in five countries-Part 1. J Community Genet. 2011;2:1–11.
53. Evers-Kiebooms G, Decruyenaere M. Predictive testing for Huntington's disease: a challenge for persons at risk and for professionals. Patient Educ Couns. 1998;35:15–26.
54. Halpern J, Arnold RM. Affective forecasting: an unrecognized challenge in making serious health decisions. J Gen Intern Med. 2008;23:1708–12.
55. Middleton A. Communication about DTC testing: commentary on a "family experience of personal genomics". J Genet Couns. 2012;21:392–8.
56. Lehmann LS, Kaufman DJ, Sharp RR, Moreno TA, Mountain JL, Roberts JS, Green RC. Navigating a research partnership between academia and industry to assess the impact of personalized genetic testing. Genet Med. 2012;14:268–73.
57. Lynch J, Parrott A, Hopkin RJ, Myers M. Media coverage of direct-to-consumer genetic testing. J Genet Couns. 2011;20:486–94.
58. Wagner JK, Cooper JD, Sterling R, Royal CD. Tilting at windmills no longer: a data-driven discussion of DTC DNA ancestry tests. Genet Med. 2012;14:586–93.
59. Ormond KE, Hudgins L, Ladd JM, Magnus DM, Greely HT, Cho MK. Medical and graduate students' attitudes toward personal genomics. Genet Med. 2011;13:400–8.
60. Perez GK, Cruess DG, Cruess S, Brewer M, Stroop J, Schwartz R, Greenstein R. Attitudes toward direct-to-consumer advertisements and online genetic testing among high-risk women participating in a hereditary cancer clinic. J Health Commun. 2011;16:607–28.
61. Rahm AK, Feigelson HS, Wagner N, Le AQ, Halterman E, Cornish N, Dearing JW. Perception of direct-to-consumer genetic testing and direct-to-consumer advertising of genetic tests among members of a large managed care organization. J Genet Couns. 2012;21:448–61.
62. Roberts ME, Riegert-Johnson DL, Thomas BC. Self diagnosis of Lynch syndrome using direct to consumer genetic testing: a case study. J Genet Couns. 2011;20:327–9.
63. Vayena E, Gourna E, Streuli J, Hafen E, Prainsack B. Experiences of early users of direct-to-consumer genomics in Switzerland: an exploratory study. Public Health Genomics. 2012;15:352–62.
64. Corpas M. A family experience of personal genomics. J Genet Couns. 2012;21:386–91.
65. Austin SEA, Hegele RA. Clinical implications of direct-to-consumer genetic testing for cardiovascular disease risk. Can J Cardiol. 2011;27:682–4.
66. Saunders KH, Nazareth S, Pressman PI. Case report: BRCA in the Ashkenazi population: are current testing guidelines too exclusive? Hered Cancer Clin Pract. 2011;9:3.
67. Sturm AC, Manickam K. Direct-to-consumer personal genomic testing: a case study and practical recommendations for "genomic counseling". J Genet Couns. 2012;21:402–12.